Modeling the Impact of Days at Sea Leasing in the Northeast Multispecies Fishery

John B. Walden
NOAA-Fisheries
Northeast Fisheries Science Center
166 Water St.
Woods Hole, MA 02543

Abstract

This paper presents a preliminary economic analysis of the impact of implementing a days at sea leasing system in the Northeast Multispecies Groundfish Fishery. Linear and non-linear programming techniques were used to estimate days at sea lease prices and evaluate profits, vessel activity, fishing effort, crew employment and changes in harvest levels compared to a system in which vessels utilize their full days-at-sea allocation and to actual performance in 2001.

I. Introduction

On August 1, 2002, the National Marine Fisheries Service (NMFS) published an interim final rule which implemented the Settlement Agreement in Conservation Law Foundation et al. V. Evans (CLF v Evans). The Settlement Agreement was the result of a lawsuit brought against NMFS for failing to restore groundfish stocks managed under the Northeast Multispecies Fishery Management Plan to levels mandated by the Sustainable Fisheries Act (SFA). Among the provisions in the Settlement Agreement was a recalculation of all groundfish vessels days at sea baselines based on their highest reported days between 1996 and 2000, with no vessel receiving less than 10 days at sea. Each vessel was then allowed to fish up to 80% of these days.

Because the Settlement Agreement reduced allowable fishing days for many vessels to what was considered below break-even levels, and below their 2001 days (Figure 1), some vessel owners lobbied NMFS for the ability to lease days at sea from other vessels. However, since this type of system did not exist anywhere in the Northeast, no information was available to guide policy makers whether or not this would be benefit industry as a whole. Furthermore, NMFS is required under various statutes to estimate the economic and social impacts of proposed actions, inform the public of these impacts, and allow for public comments. Currently, the only fishery in the Northeast managed through any type of property rights system is the Surf Clam and Ocean Quahog fishery where individual tradeable output quotas are used. The market system being requested for groundfish was different because it was for an input, not an output.

During the last 15 years there have been a number of studies of property rights systems in fisheries, with most examining individual transferable quotas (ITQ’s) (Scott 1986, 1988

Anderson 1995, Townsend 1998, Arnason 1999, Boyce 2000, Hannesson 2000). ITQ management has been used widely in both New Zealand and Australia. Markets have also been established to trade emissions both worldwide, and in the USA where they have existed for almost 25 years (Solomon, 1999; Hanley et al., 1998, Springer and Verilek, 2003). Both the ITQ and tradable emission systems generally trade outputs, such as tons of fish, or tons of allowable emissions. The market proposed for the Northeast multispecies groundfish fishery is based on input controls, in the form of individual allocations of days at sea. In the multispecies fishery, technical interactions between species (e.g. when co-occurring species are caught together in fishing gear) leads to jointly produced outputs. Therefore, regulating a single input, such as a day at sea, may be a more effective management approach than regulating outputs, providing total fishing mortality for all species can be aligned with an appropriate input level. Input controls are often easier to enforce, and at the present, have gained some degree of acceptance by the groundfish industry in New England.

A days at sea leasing system will require an economic analysis as part of the package submitted for regulatory approval. Such an economic analysis will allow decision makers to understand the benefits and the costs of the system. However, measuring the benefits and costs of such is challenging because of a large number of unknowns, particularly, determining the lease price. Models that evaluated prices in emissions markets showed a wide range of results that often differed widely from those that occurred in practice (Springer and Varilek, 2003). Factors such as transaction costs, institutional constraints, spatial differences between firms, and thinness in quota markets can all lead to prices different than those predicted by the models.

Squires, Alauddin and Kirkley (1992), and Kirkley and Squires (1995) modeled the ITQ market for Pacific Sablefish using a simulation model. Although they modeled a market for outputs, their approach can be modified to examine an input market. They used a combination of linear programming (LP) and econometrics to estimate a price for quota, and then simulated trades that would occur once a market was established. The estimation of quota price is referred to as a "virtual price" since it is derived from examining shadow prices from an initial linear programming model. The models presented below use a similar approach to estimate virtual prices for a day at sea, and then use these prices in a non-linear programming (NLP) model to simulate trades among vessels. However, instead of estimating equilibrium price, a stochastic price is generated based on the LP results, and the NLP model is run repeatedly to simulate trades at different prices.

The rest of this article is organized as follow: Section 2 details the proposed management plan; section 3 details the methodology used; section 4 shows the results; and section 5 offers conclusions.

II. Leasing Details

Under the proposed days-at-sea leasing system, vessel owners who wish to lease days at sea from other vessels must submit an application to NMFS 45 days prior to the time the vessel intends to fish the leased DAS. The vessel can only fish the leased DAS during the current fishing year[1] with the provision that up to 10 days can be carried over to the next fishing year. Applications can be filed anytime in the fishing year up until March 1, 2004. The lessee must provide information to NMFS on the number of days leased and the lease price paid.

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[1]The current fishing year runs from May 1, 2003 to April 30, 2004. The proposed regulations were to take place on August 1, 2003.

Additionally, there can be no sub-leasing of days by the lessee. The minimum increment of days at sea which can be leased is five, or the remaining amount of a vessel's allocated days at sea, whichever is less. The maximum amount that can be leased is the vessel's entire days at sea allocation. An adjustment schedule is proposed, which establishes a penalty for larger horsepower vessels leasing days from smaller horsepower vessels (Table 1). This is an attempt to limit any mortality increases which might occur due to larger vessels leasing days from smaller vessels. Vessels which have a hook gear only permit (category D) can only lease days from other Category D vessels. For allocation of future fishing rights, history of days at sea use will remain with the lessor, but only if the lessee actually fishes the days. The catch history will remain with the lessee. The Regional Administrator (RA) will have the ability to terminate acceptance of new lease applicants if, due to unanticipated impacts, it is determined that the goals of reducing fishing mortality or increasing economic opportunity would be undermined by the continued leasing of DAS.

III. Methods

A quota market which allowed vessels to trade quota among themselves was simulated using both linear (LP) and non-linear programming (NLP) models. The underlying assumption in both models is that a vessel's capital stock is fixed at the beginning of a trip, and that a vessel will therefore choose a level of effort to maximize trip profits. To determine a potential lease price, a LP model was used in which short-run profits for each groundfish vessel was maximized , by selecting a level of effort (E), subject to a constraint on catch and total effort using 2001 vessel activity. The shadow price of effort from the LP model represents the profitability of an additional day at sea for each vessel, based on the vessel's underlying production technology, the price of outputs, and a binding effort constraint. The shadow prices generated by the LP model are unique to each firm, since the LP model is run once for each vessel in the fleet. Firms would generally bid up to their shadow price of effort for quota. Shadow prices of effort for all vessels were then fit to a distribution using the program @Risk, after stratifying the vessels into three gear groups (trawl, hook and gillnet). Based on the fitted distributions, a thousand lease prices were generated for each gear type. Then, an NLP model was run 1,000 times using the generated lease prices. This approach differs from that of Squires, Alauddin and Kirkley (1990) and Kirkley and Squires (1995) in that a market clearing lease price for effort is not calculated. Rather trades among vessels are simulated using different lease prices. When uncertainty is high concerning lease price, simulating the lease market at different price levels provides a range of solutions from which mean values can be calculated. In the NLP model, trading was only allowed to take place within gear sectors. This restriction could be relaxed at a later point if necessary, but it was believed that the proposed system would restrict leasing between vessels to those of similar gear types. The first stage LP model is shown below.

$$\underset{E}{Max}\, Z_i = \sum_S P_s * CPUE_{is} * E - VC_i * E \quad (1)$$

$$s.t.$$

$$CPUE_{is} * E \leq TC_{is} \in S \quad (2)$$

$$E \leq E_{2001} * 0.99 \quad (3)$$

where:

Z_i = total short-run profit earned by vessel i

P_s = Average Price for species s.

$CPUE_{is}$ = Catch per unit effort by vessel i of species s.

E = Effort (days at sea) chosen by the model

VC_i = variable cost per day at sea

TC_s = total catch by vessel i of species s during 2001

E_{2001}= Effort in year 2001.

The model was run once for each vessel in each fleet. If equation 3 does not constrain effort, resulting in a shadow price for effort of zero, the value of E^* (optimal effort) is substituted for E_{2001} in equation 3, and the model is run again for that observation.

The NLP model used to simulate the quota market once lease prices are generated is shown below.

$$MaxZ = \sum_i TR_i - VC_i \tag{4}$$

$$TR_i = \sum_s (P_s * CPUE_{si}) * ((\sum_j W_{ij} * E_{lj}) + E_{bi}) + L_p * \sum_j E_{sj} \tag{5}$$

$$VC_i = C * ((\sum_j W_{ij} * E_{lj}) + E_{bi}) + L_p * \sum_j E_{lj} \tag{6}$$

$$s.t.$$

$$(\sum_j W_{ij} * E_{ij}) + E_{bi} \leq E_{ui} \tag{7}$$

$$(\sum_j E_{sj}) + E_{bi} \leq E_{ai} \tag{8}$$

$$TR_i \geq VC_i \tag{9}$$

$$\sum_i E_{si} = \sum_i E_{li} \tag{10}$$

$$E_{si} = 0 \quad iff \;\; E_{ai} = 8 \tag{11}$$

$$\sum_j E_{sj} * \sum_j E_{lj} = 0 \;\; \forall \, j \tag{12}$$

$$E_{lj} = 0 \; \forall \, i = j \tag{13}$$

TR_i = Total revenue earned by vessel i.

VC_i = Variable Cost for vessel i.

P_s = Average price of species S.

$CPUE_{si}$ = Catch per unit effort of species s by vessel i.

W_{ij} = Weighting factor used for a day at sea when vessel i leases days from vessel j.

E_{lj} = Days leased by vessel i *from* vessel j.

E_{sj} = Days leased by vessel i *to* vessel j.

E_{bi} = Days used by vessel i of their own allocated days.

E_{ui} = Upper bound on effort by used in a year by vessel i.

E_{ai} = Allocated days for vessel i.

L_p = Lease Price.

Equation 7 sets an upper bound on the total effort that can be expended for each vessel during the year. For trawl vessels, it was set at 150 days, and for gillnet and hook vessels, 100 days. Equation 8 ensures that vessels can only fish and lease the amount of their allocation to other vessels. Equation 9 means that an individual vessel cannot fish at a loss. Equation 10 requires the supply of leased days to equal the demand for leased days. Equation 11 prevents a vessel from leasing out days at sea if it only has an allocation of eight days. Equation 12 presents vessels from both buying and selling days at sea. Equation13 prevents a vessel from leasing quota from itself. Equations 5 and 6 define total revenue and variable cost for each vessel.

The NLP model was run 1,000 times for each fleet sector (i.e. trawl, gillnet and hook), using the randomly generated lease price values. There were some slight differences between the constraints included in the model and those proposed in the DAS leasing system. For example, the analysis did not include a constraint on the minimum days at sea that can be leased, as proposed. Additionally, it was assumed the proposed system would be in place for a full year.

IV. Results

The LP model results indicate that the average DAS lease price would be about 50% of gross revenue for all three gear categories (Figure 2). These values take into consideration crew wages and variable costs such as fuel, ice and food. The NLP results indicate that cumulative and mean profit levels under a days at sea leasing system are greater for all gear sectors compared to a system where vessels fish up to their allocated days at sea (Figures 3, 4 and 5; Table 2). This is not surprising since the NLP model maximizes profits for all vessels in a given gear sector, and trades between vessels only occur if overall profit to the industry increases. The model indicates overall effort would increase only slightly (<170) for the trawl fleet, but would increase substantially in the hook and gillnet fleets (Table 2). Under a days at sea leasing system, many fewer would fish than had fished 2001; the number of vessels would decline by 47%, 36% and 41% in the hook, gillnet and trawl sectors respectively (Table 2). The number of crew employed would also be affected. Crew days would decline (by 17-29%) in both the gillnet and trawl sectors, but increase (+42%) in the hook sector (Table 2). The increase in total crew employment in the hook sector is driven by the 109% increase in days at sea by hook vessels under the leasing system. For all three sectors combined, fewer crew are likely to be employed under a days at sea leasing scheme. However, average crew earnings will be markedly higher (20-30k higher) for those crew that are employed (Table 2). Displaced crew will not see any benefit unless vessel owners elect to share their lease revenues with them.

Although the NLP model projects higher mean profits under the days at sea leasing program, the impact on fishing mortality needs examination. Initially, the proposed leasing scheme was thought to be conservation neutral due to the penalty factors included. However, the modeling results indicate that mortality would increase substantially for some stocks if a days at sea leasing system were adopted (Table 3). Of particular concern, are the projections which showed cod catches increasing by 40%. A further evaluation of the weighting scheme used for transferring days from smaller vessels to larger vessels may help in this regard. The results are also being influenced by the constraint on allowable fishing days. In reality, 100 allowable days per vessel for the hook and gillnet sectors may be too high. Alternative variations of the NLP model could include a stochastically determined upper bound on DAS usage based on observed vessel behavior, or from interviews with vessel owners. Finally, experience in the emissions trading markets has shown that lease markets may not develop as fully as simulation models suggest (Springer and Varilek, 2003).

V. Summary and Conclusions

Linear and non-linear programming models were used to simulate a proposed days at sea quota market in the Northeast multispecies groundfish fishery. Results show that industry profits would be greater under a days at sea leasing system than if all vessels fished up to their current DAS allocation. Fewer vessels would fish under a days-at-sea leasing program and fewer crew would be employed. However, the crew that did work on vessels that leased days at sea would earn more on average, than they did in 2001. Days at sea fished would increase substantially for the hook and gillnet sectors, but only increase slightly for the trawl fleet. The major drawback with the system at this point, is that it does not appear to be conservation neutral. Mortality will increase on most groundfish stocks. Further thought needs to be given to the penalty scheme for leasing days between large and small vessels, and on other ways to limit fishing mortality.

A large number of unknowns can influence a days at sea leasing market. The LP model used was one approach to estimate potential lease price, and fitting the results to a distribution allowed a stochastic element to be introduced to the NLP model. Adding a stochastic lease price was important because the lease price for a day at sea in the absence of market information is unknown. Anecdotal information from vessel owners suggests that vessels may not actually pay for lease but instead use a share arrangement where the lessee pays the lessor a share of the catch. The NLP model returned economic results which one would expect from a market based leasing system. That is, higher industry profits and fewer vessels fishing. Because the NLP model maximizes industry profits, an actual lease market may not yield the same level of profits, or generate a large increase in fishing mortality on some stocks as predicted. Additionally, the trades in the model do not account for geographic regions where vessels operate. That is, the model could trade days from a vessel in Virginia to a vessel in Maine. This is very unlikely to occur in the initial years when markets are just forming. Building explicit geographic considerations in the model might lead to different outcomes. Further modeling is needed to reduce the amount of uncertainty, and to give policy makers clearer guidance on the benefits and costs of implementing a days at sea leasing program.

Table 1. Proposed Adjustment Factors for Trades Between Vessels of Different Horsepower

		Lessor Vessel (selling) Horsepower Class					
		0-175	176-250	251-324	325-400	201-650	651+
	0-175	1.00	1.00	1.00	1.00	1.00	1.00
Lessee Vessel	176-250	0.80	1.00	1.00	1.00	1.00	1.00
Horsepower Class	251-324	0.70	0.88	1.00	1.00	1.00	1.00
	325-400	0.58	0.73	0.83	1.00	1.00	1.00
	201-650	0.49	0.61	0.70	0.84	1.00	1.00
	651+	0.36	0.45	0.52	0.62	0.74	1.00

Table 2. Per vessel results from the simulated days at sea leasing market

	Hook	Gillnet	Trawl
Average Profit - Leasing	$85,495	$61,966	$77,367
Average Profit - No Leasing	$65,042	$45,904	$51,063
Total Effort with Leasing	2,008	9,409	33,141
Total 2001 Effort	960	7,868	33,019
Number of Vessels			
Fishing in 2001	43	164	519
Fishing Under Days At Sea Leasing	23	105	306
Leasing Days at Sea to Others	20	59	213
Percent Change in Vessels Fishing	-46.5%	-36.0%	-41.0%
Crew Employed			
Crew Days in 2001	1,787	22,733	104,847
Crew Days with Leasing	2,532	18,839	74,950
Average Crew Wages fishing at allocated days at sea	$15,710	$11,715	$21,727
Average Crew Wages under days at sea leaing	$42,527	$33,829	$51,376

Table 3. Projected change in mortality under days at sea leasing arrangement.

	2001 Landings (Metric Tons)	Landings with Leasing (Metric Tons)	Change
Cod	11,223	18,805	40.3%
Haddock	5,027	6,012	16.4%
Yellowtail Flounder	6,645	9,264	28.3%
Pollock	3,477	3,867	10.1%
Witch Flounder	2,890	3,077	6.1%
American Plaice	4,242	4,228	-0.3%
Windowpane Flounder	160	208	23.1%
White Hake	2,490	2,309	-7.9%
Redfish	352	343	-2.5%
Winter Flounder	6,289	8,102	22.4%

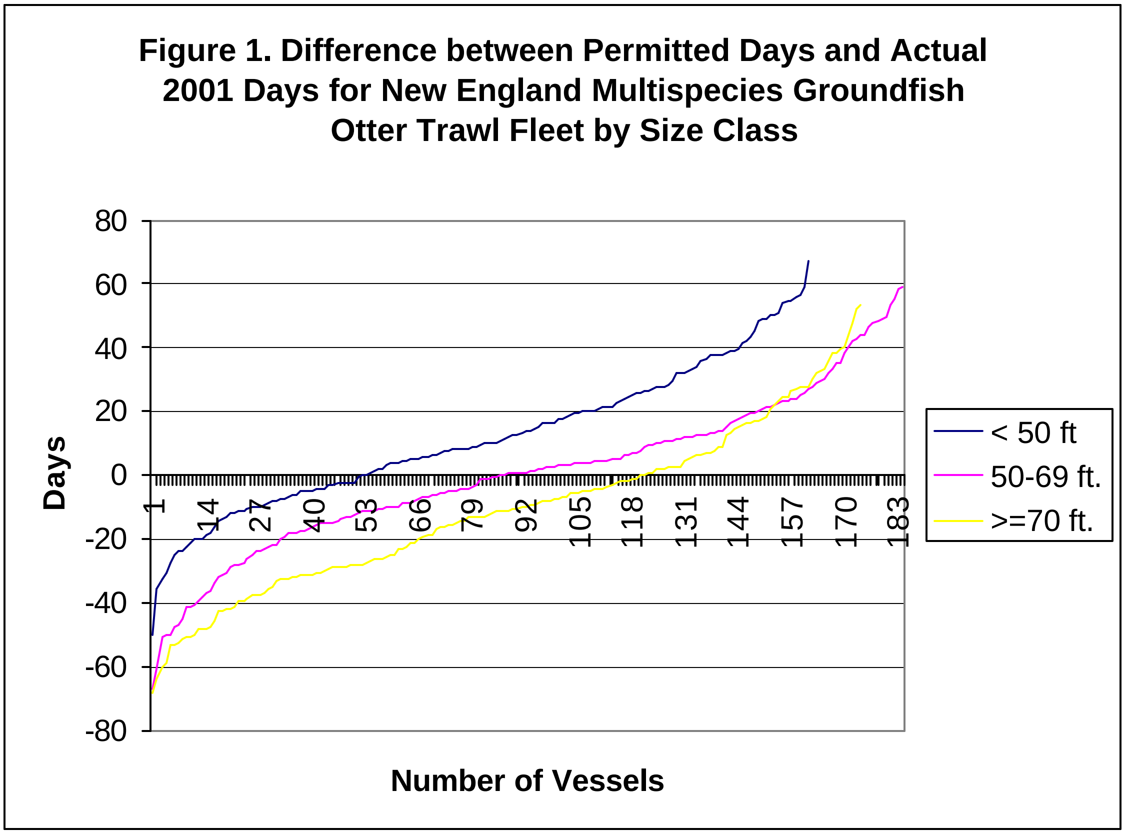


Figure 1. Difference between Permitted Days and Actual 2001 Days for New England Multispecies Groundfish Otter Trawl Fleet by Size Class
80
60
40
20
0
-20
-40
-60
-80
Days
1
14
27
40
53
66
79
92
105
118
131
144
157
170
183
Number of Vessels
< 50 ft
50-69 ft.
>=70 ft.

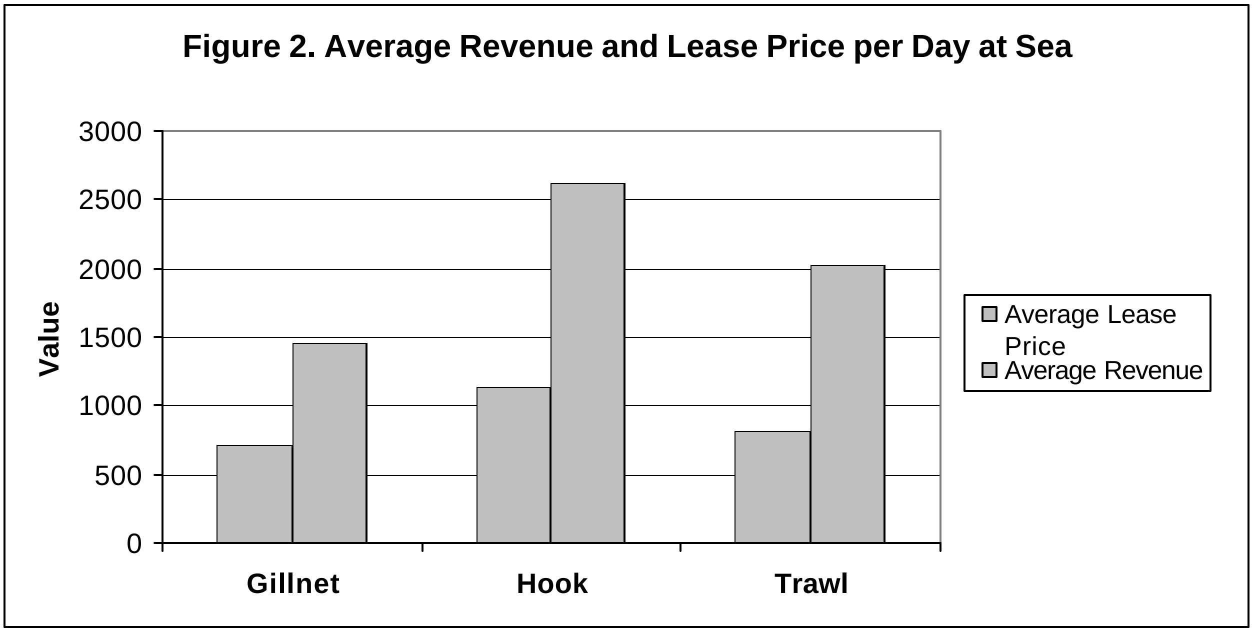


Figure 2. Average Revenue and Lease Price per Day at Sea
3000
2500
2000
1500
1000
500
0
Value
Gillnet
Hook
Trawl
Average Lease Price
Average Revenue

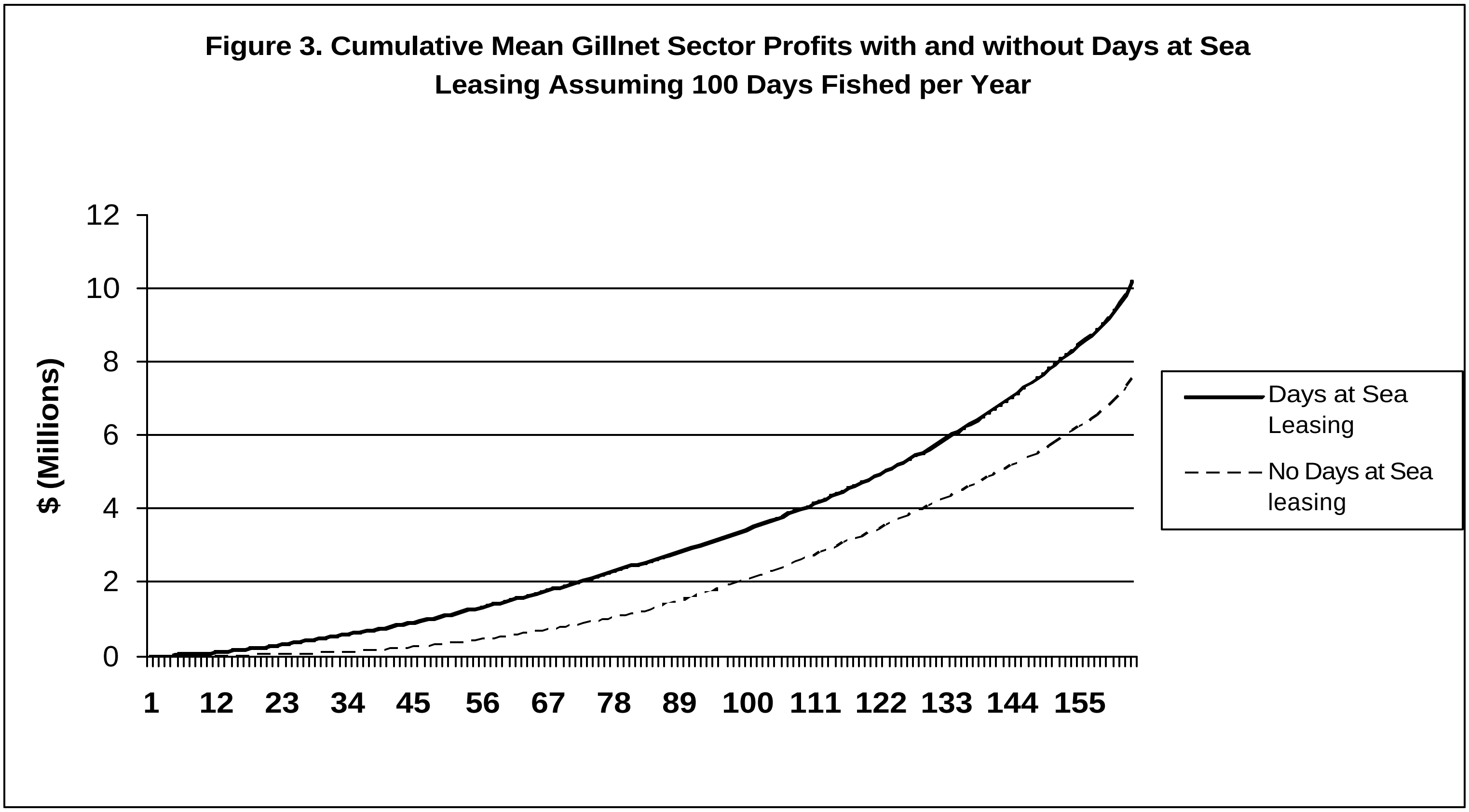


Figure 3. Cumulative Mean Gillnet Sector Profits with and without Days at Sea Leasing Assuming 100 Days Fished per Year
$ (Millions)
0
2
4
6
8
10
12
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
Days at Sea Leasing
No Days at Sea leasing

Figure 4. Cumulative Mean Hook Sector Profits with and without Days at Sea Leasing Assuming 100 Days Fished per Year

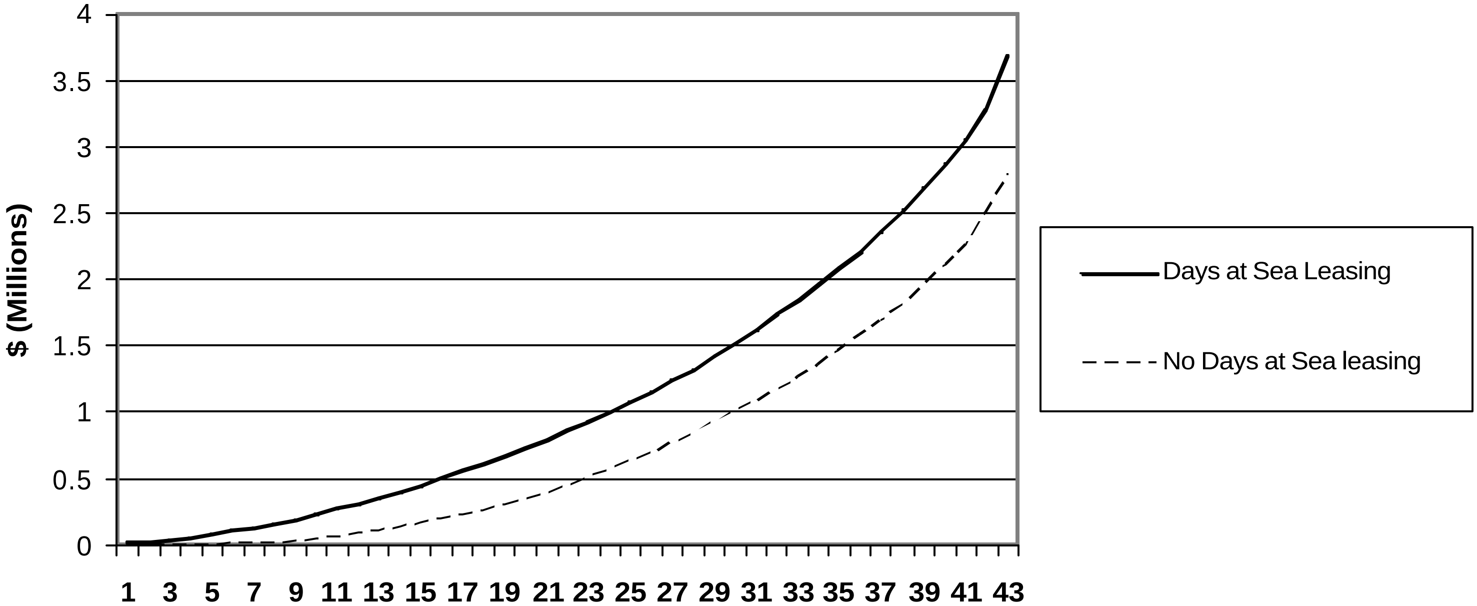
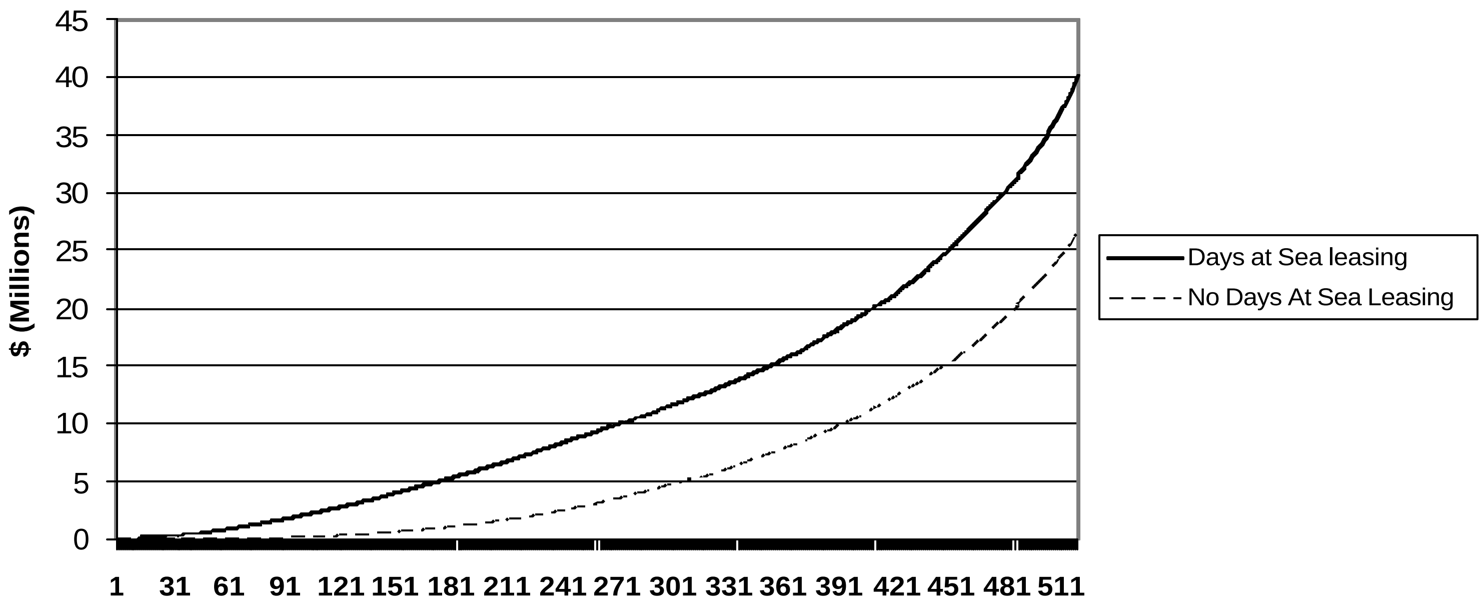


Figure 5. Cumulative Mean Profit for the Trawl Sector with and without Days at Sea Leasing Assuming 150 Days Per Year



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